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Goodwin Creek Experimental Watershed – Assessment of Conservation and Environmental Effects

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Abstract. *Goodwin Creek, a benchmark watershed of the Conservation Effects and Assessment Project (CEAP), drains 2132 ha in the north central part of the state of Mississippi. Drainage is westerly as part of the Yazoo River Basin, a tributary of the Mississippi River. Sediment yield rates (14.5 t/ha/yr) in the region are among the highest in the nation. Phosphorus and fecal coliform levels also exceed water quality standards. The effect of land use and management practices on erosion and transport of sediment and contaminants has been the major thrust of research conducted on Goodwin Creek and is an important component of the CEAP project.*

Analyses are in progress to evaluate the effects of conservation practices associated with channel and watershed management on sediment loadings throughout the watershed. Specific management practices which will be evaluated include channel bank vegetation, stream habitat improvement and management, grade and channel stabilization structures, and drop pipes. Studies to identify sediment sources are also in progress and will be coupled with measured flow and sediment data for comparison to simulations using a combination of the AnnAGNPS watershed model and the CONCEPTS channel-evolution model. Several management/climatic scenarios will be assessed using these two models to identify the most cost-effective suite of management practices to safeguard downstream water quality.

Keywords. *experimental watershed, Conservation Evaluation and Assessment Project (CEAP), water quality, conservation practices, sediment transport, bank stability, watershed and channel-evolution models, impacts on aquatic biota.*

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Introduction

The Goodwin Creek Experimental Watershed (GCEW) is a major research watershed of the Agricultural Research Service (ARS) and one of 12 benchmark watersheds of the Conservation Effects Assessment Project (CEAP) a cooperative project of the ARS and Natural Resources Conservation Service (NRCS). The benchmark watersheds are a key component of the Watershed Assessment Studies (WAS) part of CEAP and have been located in strategic parts of the country to assess the differing problems and solutions particular to a region. The principal focus of the CEAP effort is to produce an assessment of environmental effects and benefits derived from implementing USDA conservation programs. The data and studies from the benchmark watersheds will provide evaluation of management practices on water quality and aquatic habitat, and yield needed improvements to channel and watershed models for use in managing agricultural watersheds and improving national assessments.

Goodwin Creek Watershed

Characteristics

Goodwin Creek drains 2132 ha in Panola County which is in the north central part of the state of Mississippi (Fig. 1). The watershed is located in the loess-covered bluff hills province of the Yazoo River basin, which is just east of the Mississippi River floodplain. The watershed is divided into 13 sub watersheds, which range in size from 28 to 1292 ha. Elevation on the watershed ranges from 71 m (233 ft) to 128 m (420 ft) above sea level, with an average channel slope of 0.004 m.

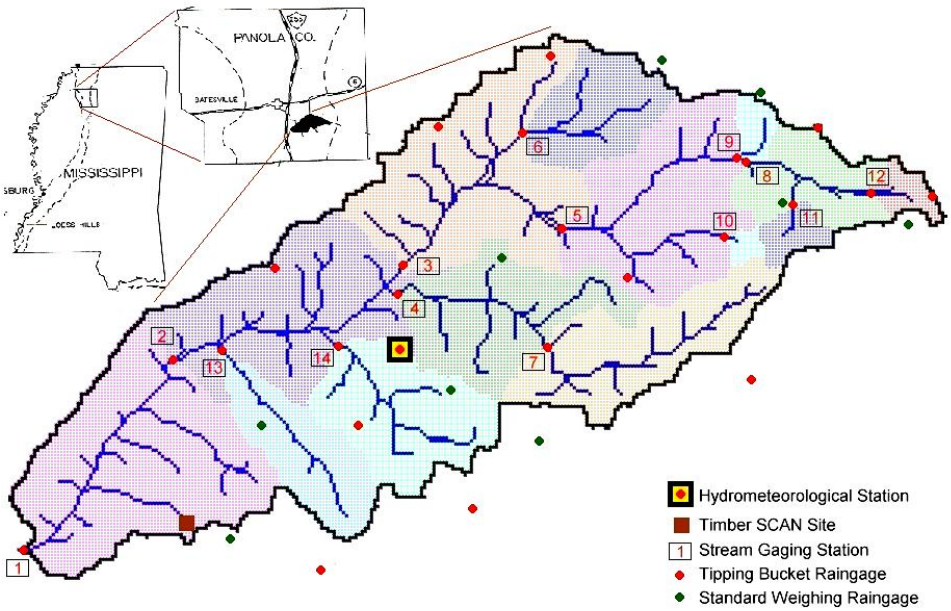

Figure 1. The Goodwin Creek Experimental Watershed, Panola County, Missisippi.

The soils on the watershed consist of two major associations. One soil association is the Collins-Falaya-Grenada-Calloway association that is mapped in the terrace and flood plain locations. These soils are poorly to moderately well drained and include much of the cultivated area in the watershed. The other soil association, the Loring-Grenada-Memphis association, is developed on the loess ridges and hillsides. These soils are moderately well to well drained on gently sloping to very steep surfaces and include most of the pasture and wooded area of the watershed. The soils are silty in texture and quite easily eroded when the vegetation cover is removed.

The climate on the watershed is humid, with average daily maximum temperatures of about 30^0 C in summer and 10^0 C in winter. Average annual rainfall of the watershed, measured at the climatological station near the center of the watershed, is 1440 mm, while the mean annual runoff has been determined to be 145 mm at the watershed outlet. Most major runoff events occur during winter and spring seasons. Land use on the watershed has changed from nearly equal portions of cultivated, pasture, and wooded in 1980 to 10% cultivated at the present time (Fig. 2). Cultivated land is primarily composed of cotton, soybeans, and corn (see Alonso and Bingner, 2000).

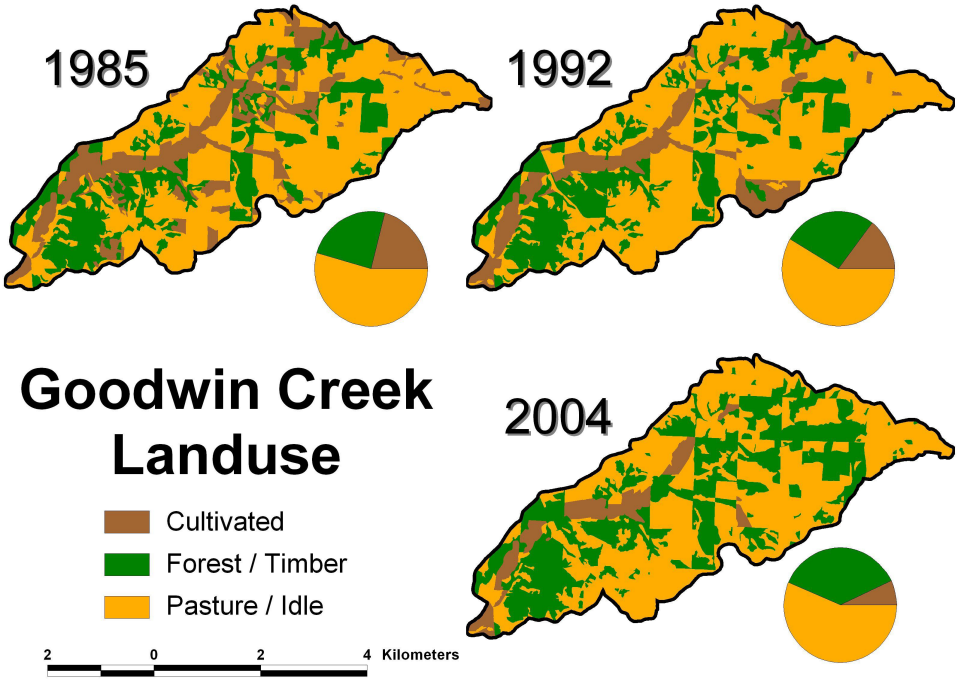

Figure 2. Land use change on Goodwin Creek.

Environmental Concerns

Sediment yield rates in this region (14.5 t/ha/yr) are among the highest in the nation. The soil quality of the land surface has been locally adversely affected by excessive erosion.

Suspended sediment concentrations regularly reach thousands of mg/l during storm runoff (Fig. 3). Negative impacts on aquatic biota in streams and rivers in this region have been linked with high suspended sediment loadings (Fig. 4). Aquatic habitat has been impaired by processes associated with channel incision, including flashy hydrology, loss of large wood, frequent movement of bed sediments, and loss of cover and pool habitat (Shields et al., 1994). Phosphorus and fecal coliforms have also been established as impairing water quality.

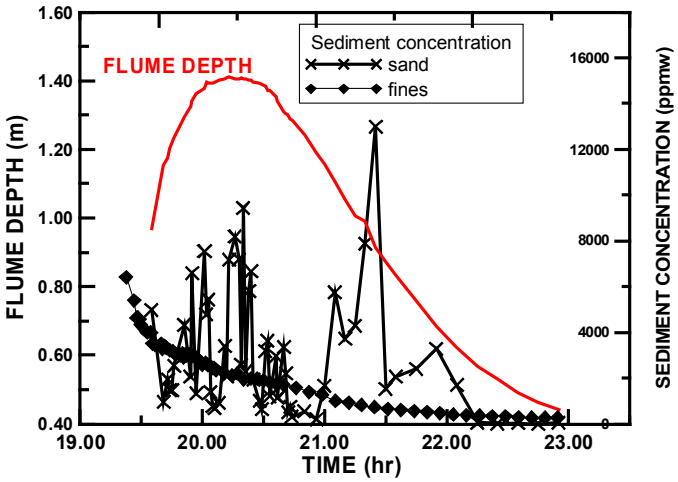

Figure 3. Example flow and sediment concentration data for sand (0.062-2.0 mm) and fine (< 0.062 mm) sediment collected during a runoff event at station 2 on 08/27/86.

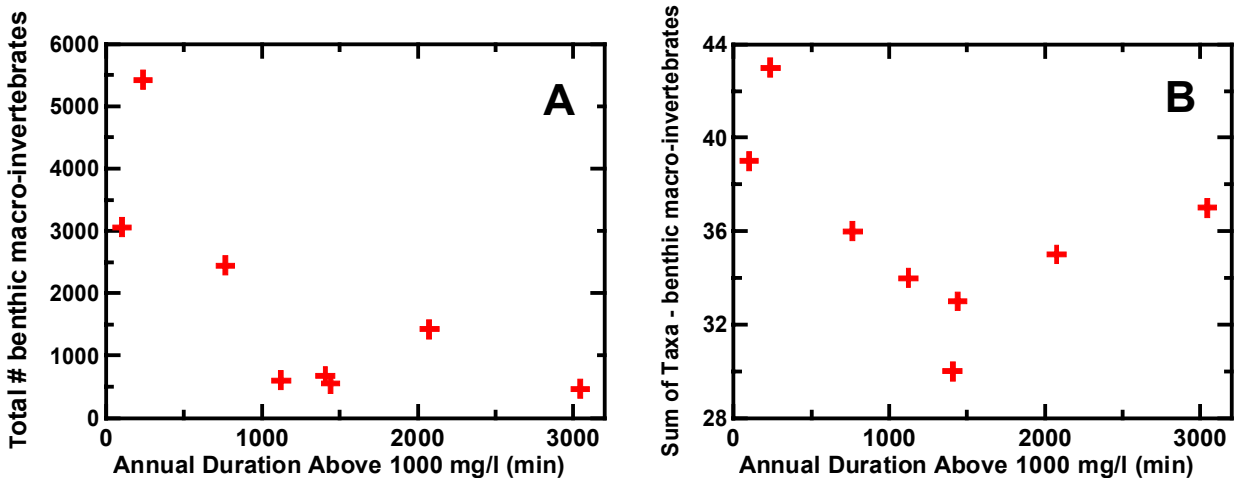

Figure 4. Total number of organisms (A) and number of taxa (B) of benthic macro-invertebrates as related to the annual continuous expected duration of suspended sediment concentration above 1000 mg/l. These data were collected on eight Demonstration Erosion Control (DEC) watersheds, including Goodwin Creek, located in northern Mississippi (Kuhnle et al., 2001).

Measurements in Place

Rainfall, runoff, and climatic variables have been continuously collected on the watershed since 1982. Land use surveys have also been conducted annually since 1982. Sediment transport sampling has occurred from 1982-1993 and from 2003 to the present in all sub watersheds. Bank erosion processes have been studied on the watershed from 1980 to the present. Water quality samples have been collected from 1985 to the present. Data on fish, invertebrates, and habitat between stations 1 and 2 have been collected between 1991-1996 and 2003-2004. Specific details on data collection in the watershed can be found in Blackmarr (1995). To add to this data set, detailed information on specific land management practices is being obtained from NRCS.

Research Objectives

The objectives on the watershed relating to CEAP consist of:

1) Evaluating changes in land use, conservation practices and channel responses as they affect water in regards to sediment and nutrients.

2) Quantify source areas of sediment within the watershed – overland (sheet and rill), gullies (ephemeral, edge-of-field), or channel boundaries.

Approaches

The research related to CEAP on Goodwin Creek will combine field, laboratory, and computer modeling components. The field and laboratory studies will concentrate on the accurate measurement and prediction of sediment transport rates by the channels of the watershed. This capability is critical for the accurate determination of sediment yields, sources, and contaminants. A key factor that will be studied on Goodwin Creek is the determination of the effects of sediment loads on the environment. Previous studies have shown that channel erosion provides a significant contribution to the total sediment load of the watershed (Grissinger et al., 1991; Kuhnle et al., 1996). Samples of fine sediment in transport automatically collected at the 13 measurement stations will be combined with experimental measurements of sediment concentration and bed forms collected using acoustic backscattering to yield a record of total sediment load. Soil properties of the watershed will be quantified and used for sediment source determinations and modeling inputs.

Completed (historical) studies have documented the effects of channel and bank stabilization on stream fishes and invertebrates. In particular, populations within reaches stabilized using traditional structures and reaches with structures modified to produce more pool habitat have been compared over 3-10 year periods (Shields et al., 1998). Some of these studies have documented the temporal variation in bed material size with channel erosion and deposition and the hydraulic retention at baseflow of reaches with and without small beaver dams.

To evaluate the effect of land use change, new information on land management practices will be obtained from NRCS to supplement the historical data base of the watershed. This information will consist of the following data: land areas, timing of Conservation Reserve Program (CRP) lands, EQIP projects including the time of installation and location of drop pipes, channel stabilization measures including grade control structures, flow training structures, rip-rap and other bank control structures, and also methods of stabilizing channel banks using vegetation.

To facilitate the fulfillment of these goals the land use of the entire watershed from 1982 to the present has been converted to digital records. The information on management practices is being added to this digital data set. This will greatly improve the ability to input the data into watershed models and simulate different patterns and timing of land use scenarios. Land use surveys are being automated by using remote sensed imagery. The time required for data collection will be decreased and the accuracy of the land use surveys will be improved. The main types of land use on the remote imagery will be calibrated with ground truth data.

Sediment source information of the suspended sediment of Goodwin Creek during runoff events is being determined using activities of ^{7}Be and ^{210}Pb (Wilson and Klaner, 2005). Suspended sediment in Goodwin Creek is a mixture of landscape derived and bank derived sediment. The activities of ^{7}Be and ^{210}Pb of the surface soils have been found to be significantly higher than corresponding activities of the bank sediments. Fine suspended sediment in Goodwin Creek has an intermediate radionuclide signature that is quantified in terms of the relative contribution of landscape derived and bank sediment (Fig. 5A). The radionuclide signature of the suspended sediment will lie intermediate along a mixing line between the signatures of the two end-member sources of sediment. Activities of ^{7}Be and ^{210}Pb are measured from precipitation, soil, bank, and suspended sediments in the Goodwin Creek watershed using gamma spectroscopy. Preliminary findings on the changes in the relative fractions of the two sources of sediment during a runoff event in 2004 are shown in Figure 5B to illustrate the capability of this technique. This data will be valuable in evaluating predicted sediment source information generated from CONCEPTS (Langendoen, 2000) and AnnAGNPS (Bingner and Theurer, 2001).

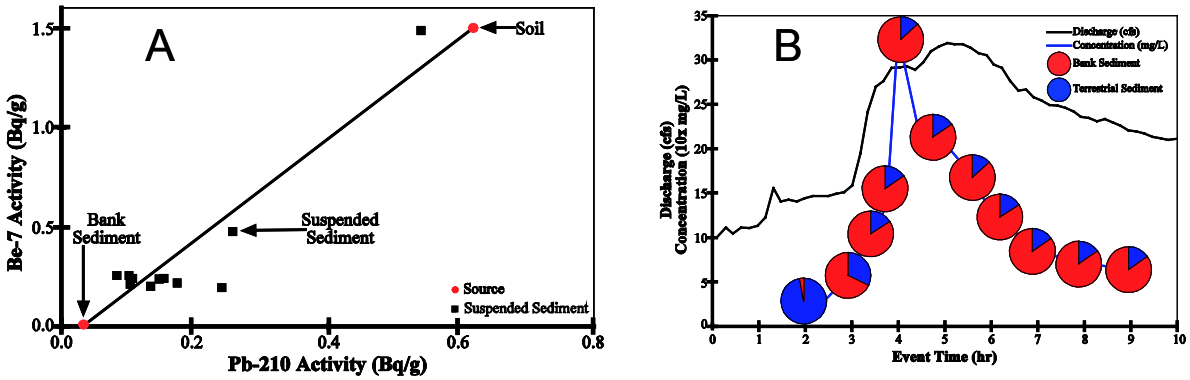

Figure 5. (A) The radiocnuclide signatures of soil, channel bank, and suspended sediment are shown for Goodwin Creek. (B) Preliminary results from a runoff event in April of 2004 illustrate the changes in relative sources during the runoff event.

Continuous monitoring of hydrologic, hydraulic and geotechnical controls of streambank failures is being conducted along an active meander bend (Simon et al., 2000; Wood et al., 2001) and at edge of field gullies. The data from these studies are used to enhance a deterministic model of bank stability, to support finite-element modeling of seepage, and to develop a predictive model of gully migration and erosion. Top-bank vegetative treatments are being monitored to quantify the hydrologic and mechanical effects of riparian vegetation on bank stability and their potential role as a conservation measure (Pollen et al., 2004). These efforts will provide data for enhancements to routines in CONCEPTS and AnnAGNPS.

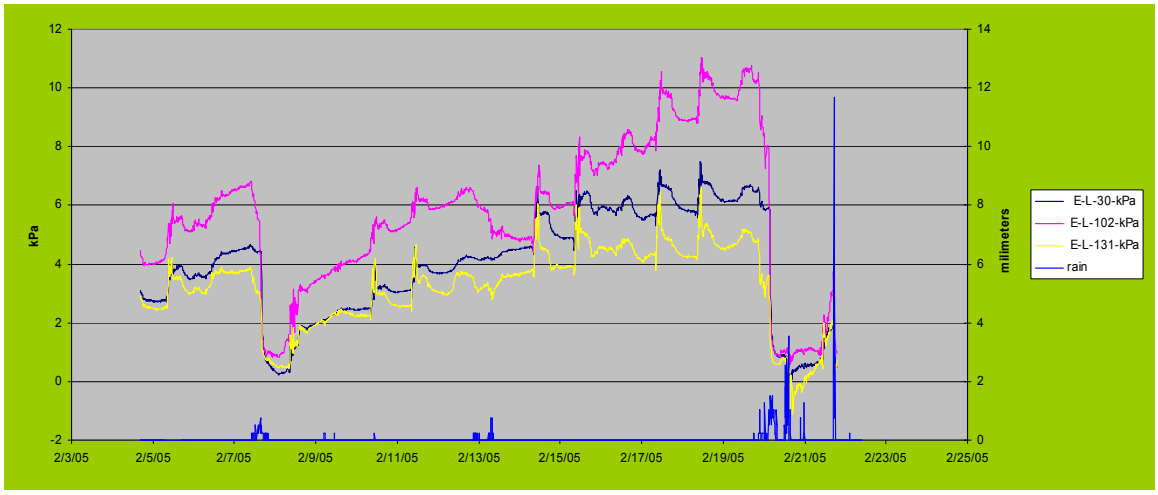

Figure 6. Monitored changes in matric suction with time from the bendway study site on Goodwin Creek. Matric suction is a key variable in the prediction of bank instability.

The historical and newly acquired conservation data from NRCS will be used with AnnAGNPS and CONCEPTS to evaluate watershed and channel responses to conservation practices over the period of record of the watershed. The simulated values will be verified using field-collected data on sediment concentrations, sediment sources, and bank retreat rates. This will ensure that the models adequately represent the processes acting on the watershed. Model simulations using AnnAGNPS and CONCEPTS will be made to evaluate different scenarios of conservation practices and sources of sediment. Changes in water quality parameters from 1985 through 2005 will be evaluated in terms of the conservation practices used on the watershed and optimized management practice scenarios will be developed.

Collaborators and Cooperating Agencies and Groups

NRCS has established two SCAN (soil climate analysis network) sites on Goodwin Creek. These sites provide long-term geographically distributed soil climatology data. Soil moisture and temperature at several different depths are being measured at a wooded and at a pasture site.

NOAA has identified Goodwin Creek for co-location of solar surface radiation budget (SURFRAD) and surface thermal energy and CO_2 exchange (FLUXNET) monitoring stations as part of nationwide networks. Data on those parameters is being collected on a continuous basis and related to other watershed processes.

University of Mississippi National Center for Physical Acoustics (NCPA) has been involved in ongoing cooperative projects focused on the use acoustics to improve the measurement of sediment transport on Goodwin Creek.

Conclusions

The Goodwin Creek Experimental Watershed has been designated as a benchmark watershed in the joint NRCS and ARS Conservation Effects Assessment Project (CEAP). The historic data collection of land use, rainfall, runoff, sediment and nutrient loadings, channel erosion, and aquatic habitat studies along with current studies on sediment transport rates, bank erosion, gully processes, sediment sources, and model simulations make it an excellent site to evaluate

the effectiveness of management processes and develop improved land management scenarios for agricultural watersheds. The combination of field data collection and modeling provides the essential ingredients to evaluate existing conditions, evaluate and improve model performance, and develop new optimized scenarios for responsible land management.

Acknowledgments

The Goodwin Creek Experimental Watershed could not have been operated successfully without all of the past and present crew of dedicated watershed workers. Countless nights and weekends of storm duty were required to collect much of the sediment transport data in the historic data set. Countless other hours were spent analyzing samples and compiling data into usable formats.

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